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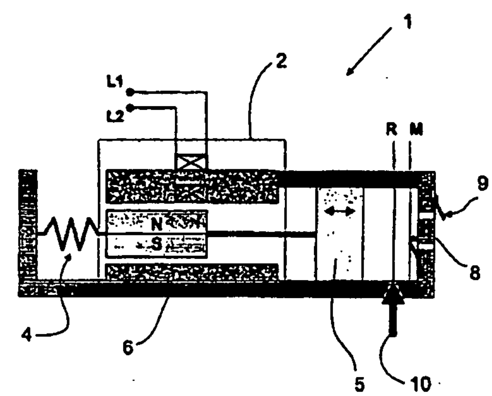

(57) Abstract: A method of controlling a compressor (1) is described, particularly a method that prevents the piston (5) from knocking against the valve system (8, 9) provided therein. The present invention has the objective of controlling the stroke of the piston (5) of a linear compressor (1), allowing the piston (5) to advance as far as the end of its mechanical stroke in extreme conditions of load, without allowing the piston (5) to collide with the valve system (8, 9). This objective is achieved by means of a method of controlling a compressor (1), particularly a linear compressor, which comprises a piston (5), and a linear motor (2), the piston (5) moving along a stroke and being driven by the motor (2), an average voltage (Vm) being applied to the motor (2) and controlling the movement of the piston (5), the method comprising the steps of measuring a first time of movement of the piston (5), comparing the first time with a foreseen time of movement, altering the voltage (Vm) if the first movement time is different from the foreseen movement time, the foreseen movement time being such that the movement of the piston (5) will reach a maximum point (M), the point (M) being substantially close to the end of the piston stroke. A system for monitoring the position of a piston (5) of a linear compressor (1), as well as a compressor (1) are also foreseen.

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METHOD OF CONTROLLING AND MONITORING PISTON POSITION IN A COMPRESSOR

The present invention refers to a method of controlling a compressor, particularly a method that prevents the piston from knocking against the valve system provided therein, as well as to a system of monitoring the position of a compressor piston, and the compressor equipped with a piston position monitoring system.

Linear-type compressors are known from the prior art and are composed of a mechanism in which the piston makes an oscillating movement and, in most cases, there is an elastic means interconnecting the cylinder and the piston, imparting a resonant characteristic to this movement, the energy being supplied by means of a linear displacement motor.

Description of the Prior Art

In a known solution (A-US 5,704,771 – Sawafuji Electric), the stroke of the piston is primordially proportional to the level of voltage applied to the linear motor, which is of the fixed-magnet-and-moveable-coil type. In this solution the mechanism is built in such a way, that the relationship between the extent of the stroke and the diameter of the piston is large, such that the variation of the end position reached by the piston during its oscillating movement, due to variations in feed voltage and load, does not to interfere significantly with the characteristics of efficiency and capacity of cooling the compressor.

In this solution the mechanism is provided with a discharge valve built in such a way that, if the piston exceeds the maximum stroke expected in its oscillating movement, for instance when the voltage applied to the motor is excessive, the piston will contact the discharge valve, and the latter will allow for some advance of the piston, thus preventing an impact against the valve-head plate.

In another known solution, the stroke of the piston is also primordially proportional to the voltage applied to the linear motor, which is of the "moveable magnet and fixed coil" type (B – US 4,602,174 – Sunpower, Inc.)

In this solution the design of the mechanism does not have a mechanical limiter for the piston stroke and is not sized to bear the excess shock of the piston against the valve plate. Due to the search for a design that is more optimized in

efficiency, the relationship between the stroke and the diameter of the piston is not great, which makes the performance of the compressor more dependent upon variations in the piston stroke. As an example, the process of discharging the gas takes place in a very small portion of the stroke, about 5% of the total.

Another effect that occurs in this type of compressor is the displacement of the medium point of the oscillating movement, having the effect of displacing the piston away from the discharge valve. This is due to the elastic deformation of the resonant mechanical system formed by the piston and a spring, when there is difference in pressure between the two sides of the piston. This displacement of the medium point of the oscillating movement is proportional to the difference in pressure between the discharge and suction.

For the above reasons, in this solution, it is necessary to use a controller of the piston stroke, which is a controller of the voltage applied to the linear motor, re-fed by the information of piston position, basically estimated from the information of current supplied to the motor and the voltage induced in the terminals of the motor (C – US 5,342,176, US 5,496,153, US 5,450,521, US 5,592,073).

Another procedure employed for providing re-feed to this voltage controller is to observe if the shock of the piston against the valve plate, detected by means of a shock-detecting microphone or an acceleration meter (solution D), which generates a command for reduction of the voltage applied to the motor and, consequently, of the piston stroke.

Drawbacks of the State of the Art

In solution (A) the piston stroke is not controlled the design can allow variations in voltage and load, without any damage to the mechanism, but this brings limitation of efficiency to the product. In this solution too, the possible shocks of the piston against the discharge valve, even if not impairing the reliability of the product, entail an increase in noise.

In solution (C) the piston stroke is controlled, by taking as a reference the estimated position of the piston, calculated from the current and voltage at the terminals of the motor, but it falls into errors due to the constructive variations of the motor, variations in temperature and in load, thus hindering a more precise control, which limits the efficiency and the operation in extreme conditions of cooling capacity.

Another drawback of this solution is that calculation of the displacement of the

medium point of the oscillating movement becomes imprecise, which is basically caused by the average difference between the suction pressure and the discharge pressure and the elastic constant of the spring of the resonant system.

In solution (D) the maximum piston stroke is controlled by maintaining the voltage applied to the motor at a level right below that which causes collision, which is achieved by detecting collisions and, on the basis of the information obtained, reducing the applied voltage slightly.

The drawbacks of this solution are the collisions themselves, which are necessary for informing the proximity of the piston to the valve plate, since they cause noise and some mechanical damage, which reduces the useful life of the product.

Another disadvantage is the relatively slow reaction of this form of control, incapable of preventing collisions and reductions in the cooling capacity during periods in which sharp oscillations in feed voltage, usual in the public network.

These limitations in the more precise control of the piston stroke represent a great limitation of performance for this type of compressor. The ideal situation would be to allow the piston to come as close as possible to valve plate, without a collision occurring. The controls known from the prior art do not permit this approximation, because there is no precision in estimating the position of the piston, and it is necessary to maintain a longer security distance, which leads the compressor not to pump gas when the discharge pressure is high, and reduces the maximum possible efficiency due to the dead volume.

Objectives and Brief Description of the Invention

The objectives of the present invention are:

- to control the stroke of piston of a linear compressor, allowing the piston to advance as far as the end of its mechanical stroke, even in extreme conditions of load, without allowing the piston to knock against the valve system.
- to control the stroke of piston of a linear compressor, allowing the piston to advance as far as the end of its mechanical stroke, even in extreme conditions of load, without allowing the piston to knock against the valve system, even in the presence of extreme disturbances from the energy supply network;
- to provide control over the stroke of the piston of a linear compressor, without the

need for information on the displacement of the medium point of piston oscillation;

- to provide control over the amplitude of the oscillation stroke of a linear compressor, permitting control over the cooling capacity developed by the compressor.

These objectives are achieved by means of a method of controlling a compressor, particularly a linear compressor, which comprises a piston and a linear motor, the piston moving along a stroke and being driven by the motor, a medium voltage being applied to the motor, and by controlling the movement of the piston, the method comprising the steps of measuring a first time of piston movement; comparing the first time with a predetermined movement time; altering the voltage if the first movement time is different from the predetermined movement time, the predetermined movement time being such that the movement of the piston will reach a maximum point, the maximum point being substantially close to the end of the piston stroke.

A system for monitoring the position of the piston of a compressor is also foreseen, with a view to preventing the piston from knocking against the valve plate located at the end of the piston stroke. This objective is achieved by means of a piston-position monitoring system, particularly a piston of a linear compressor, the piston moving along a stroke and being driven by a motor, the motor being driven by voltage, the system comprising an electronic circuit, capable of monitoring the movement of the piston from the passage at a point close to a point close to the end of the piston stroke.

It is also an objective of the present invention to provide a compressor having a monitoring system that prevents the piston from advancing as far as the end of its mechanical stroke, even in extreme conditions of load, without allowing the piston to knock against valve system. This objective is achieved by means of a compressor, particularly a linear compressor, which comprises a piston, a valve plate and a linear motor, the piston moving along a stroke and being driven by the motor, the compressor comprising an electronic circuit, capable of monitoring the movement of the piston from the passage at a point close to a point defined in a region close to the valve plate.

Brief Description of the Drawings

The present invention will now be described in greater detail with reference to an embodiment represented in the drawings. The figures show:

Figure 1 – a schematic view of a linear compressor, where the method of the present invention is applied;

Figure 2 – the behavior of the piston of the compressor illustrated in figure 1, and the behavior of the electric voltage applied to the motor that controls it;

Figure 3 – a block diagram of the method of the present invention;

Figure 4– a graph illustrating the correlation between the displacement of the piston and the voltage applied to the linear motor;

Figure 5 - a schematic diagram of the inverter that controls the motor; and

Figure 6 – a block diagram showing how the sensor actuates on the inverter by means of a microcomputer.

Detailed Description of the Invention

Figure 1 schematically illustrates a linear-type compressor 1, which is provided with a piston 5 housed within a block 6, where its stroke and movement are defined, and is driven by a linear motor 2. The piston 5 makes an oscillating movement of the resonant kind by action of a spring 4, the control of its movement being effected by means of an electronic circuit 40, which includes an inverter 50 and a microcontroller 41, the inverter 50 being capable of altering the amplitude of its stroke. Close to the end of the piston stroke there is a valve plate 8,9, against which the piston 5 knocks in the event of an external disturbance that causes alteration in the movement of said piston 5.

Control and alteration in amplitude are effected by means of re-feed 31, which is measured at a point "R" physically defined within the block 6 along the stroke of the piston 5, as shown in figure 3. Specifically, the objective of the present invention uses information of the remain time "to" of the piston 5 beyond the point "R" close to the end of the maximum possible stroke "M" for the piston 5, duration time of the

complete cycle "tc", and information of the time "tom" corresponding to the maximum possible stroke "M" for the piston 5 illustrated by means of the curve "Pm" in Figure 2, the average voltage "Vm" applied to the motor being incremented in case the time "to" is shorter than a desired time "tod" and vice-versa, maintaining the desired displacement "P" to supply a determined cooling capacity of the system where the compressor 1 is employed.

The time "to" or first time of movement of the piston 5 is the average of the last measurements of the time "to(n)", "to(n-1)", ..., and the time "tod" or the foreseen time of movement corresponds to the remain of the piston 5 beyond the point "R" for the desired stroke "P", shorter than "M". This desired stroke "P" is defined by the demand for refrigeration by the system.

In addition to the control over the average voltage "Vm", the difference in time between the moment "to(n)" (or first time of movement) of passage by the piston at the point "R" and the moment "tc(projected)" (or foreseen time of movement) expected for this passage by the point "R", defined as being the average duration of the previous cycles "tc(n)", "tc(n – ')", ..., enables one to impose a correction "dV" on the voltage "V1" applied to the motor, which is different from the desired voltage "V2", during the cycle in course, specifically during the period in which the piston 5 passes by the point "R" and the expected moment for passage by the point of maximum amplitude "P" and thus seeking to correct the path in that cycle, maintaining the stroke "P2" very close to the desired value "P3" and preventing the piston 5 from knocking against the valve plate 8,9, which would occur if the path of the piston 5 continued as illustrated in the curve "P1" and "P4" from the beginning of the disturbance "D" in Figure 2.

The point "M" is very close to the valve plate, typically remaining at a distance of a few dozens of micrometers.

The point "R" is located close to the valve plate, typically remaining at a distance of 1 - 2 millimeters.

By way of example, considering a compressor 1 with resonance frequency of 50 Hz and piston 5 stroke on the order of 16 mm, positioning the sensor "R" at about 2 mm from the valve plate 8,9, we have a time "to" that varies from zero to a maximum time "tom" of about 3,9 ms, depending upon the refrigeration capacity required. The time "tc(projected)" would be of 20 ms (1/50 Hz), and the time "tc(n) typically varying 5% with respect to the "tc(projected)". This range of 5% is a

consequence of disturbances in the feed network 35.

The measurement of these times is typically carried out by using a temporizer, which can physically be a "timer" existing in a microcontroller 41. In the measurement of "to", for instance, when the logical level from the sensor 10 installed at the point "R" passes from 0 to 1, indicating that the piston 5 is in the region beyond the point "R", one begins the measurement of the time "to", which ends when the sensor 10 informs that the piston 5 has returned to a position on this side of the point "R", characterized by the passage of the logical level from 1 to 0. In the same way, a second temporizer will measure the time passed between the moment when the piston 5 advanced beyond the point "R" in the present cycle and the moment when the piston 5 passes by this point again in the following cycle, resulting in the time "tc(n)".

The desired time "tod" should be defined according to the cooling capacity required, and there is a maximum permissible value for "tod", which corresponds to "tom" when the piston 5 is at its maximum stroke. The longer the time "tod" the greater the cooling capacity, and a corresponding table between the cooling capacity and the value of "tod" should be defined for each model of compressor. The time "tod" may also be expressed as a portion "k" of "tom", for example tod = k . tom. The time "tod" varies according to the need and ranges from zero to a value equal to "tom", and so the portion "k" varying from 0 to 1.

The method of the present invention, as well as the system of monitoring the piston 5, enables one to estimate, at each cycle, the oscillation amplitude of the piston 5 with much greater precision, permitting reaction of the electronic control to compensate variations in the cooling capacity, which are slow variations, maintaining the average amplitude of the oscillation stroke of the piston 5 at the desired value equal to "P", and also permitting rapid reactions of the electronic control for counterbalancing sharp variations in the operational conditions, caused by fluctuations in the feed voltage 35, and these corrections should be imposed at each oscillation cycle, so as to correct the amplitude of the stroke of the piston 5 at the final part of its path, after passing by the physical point of reference "R".

In the cases of sharp elevation of the voltage, the correction of the stroke is made by increasing or decreasing the value of voltage "V" and, consequently, of the tension "Vm" applied to the motor at a value "dV" proportional to the difference between the times "tc(n)" and "tc(projected)".

When the demand of the compressor 1 varies, or when slow alterations in the electricity feed network occur, the average voltage "Vm" applied to the motor is changed if the time "to" of remain of the piston 5 beyond the point "R" is different from a desired value "tod", increasing the average voltage "Vm" if "to" is shorter than "tod" and decreasing the average voltage "Vm" applied is "to" is longer than "tod".

As can be seen from figures 5 and 6, the electronic circuit 40, which includes the inverter 50, controls the motor 2 by means of the value "Vm", receives a re-feed 31 from a sensor 10 installed inside the compressor 1, thus controlling the movement of the piston 5.

A preferred way of raising and lowering the value of "Vm" is by employing PWM-type modulation, which applies, by controlling the keys Q1, Q2, Q3, Q4, a variable (and controllable) voltage value to the terminals of the linear motor 2 for varying the work cycle of this modulation. Typically, a frequency of about 5 kHz is used for this PWM modulation of the voltage on the motor 2. An embodiment example of this type of circuit is illustrated in figures 4 and 5.

In order to carry out the control of value "dV", one changes the PWM cycle, which, for few modulation cycles, may pass abruptly from a "work cycle" of 80% to 50%, for example, during this variation for a few milliseconds, only to ensure correction of the piston stroke after a sharp disturbance coming from the feed network.

The control of the inverter 50 is carried out by means of the sensor 10, which actuates by triggering temporizers that measure the times "to(n)" and "tc(n)". The calculations of the average value of the last cycles and the other calculations of comparisons between the times measured with the times "tom" and "tc(projected)" stored therein will be carried out by the microcontroller 41. The result of these calculations is the value of the cycle of application of the voltage "Vm" to the motor 2 to obtain the required cooling capacity. The result of these calculations is also the sharp and temporary variation of this cycle of PWM voltage application, temporarily correcting the voltage "dV" to compensate sharp changes in voltage, as for example transients from turning off a motor connected to a near point of the electric network 35.

The method and system and, consequently, the compressor 1, have as advantages rapid reaction, corrections at each cycle, without the need for estimates based on the voltage and current applied to the motor 2 and free from errors due to

secondary variations such as temperature, construction of the motor 2 and displacement of the medium point of oscillation of the piston 5 due to the average difference in pressure between the faces of the piston 5. It also enables one to implement a control that effectively maintains control over the piston 5 stroke, independently of the required cooling capacity, and capable of preventing mechanical collision of the piston 5 against the valve plate 8,9, even in the presence of rapid disturbances caused by the natural fluctuation of the voltage in the commercial network of electric energy 35.

As illustrated by way of example in figure 4, a voltage V1 lower than a voltage V2 is necessary to achieve the same amplitude of the piston 5, when a load C2 is greater than C1, respectively.

Detection of the passage of the piston 5 by the physical point defined as "R" may be effected by means of a physical sensor 10 installed inside the compressor 1, of the contact type, optical type, inductive type or an equivalent one. This detection may also be effected by adding a magnetic disturbance added to the voltage present at the terminals of the motor 2, this disturbance being created by a constructive detail of the magnetic circuit of the motor, for example.

A preferred embodiment having been described, one should understand that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, which include the possible equivalents.

CLAIMS

1. A method of controlling a compressor (1), particularly a linear compressor, which comprises a piston (5) and a linear motor (2), the piston (5) moving along a stroke and being driven by the motor (2), an average voltage (Vm) being applied to the motor (2) and controlling the movement of the piston (5), the method being characterized by comprising the steps of:

- measuring a first time of movement of the piston (5);
- comparing the first time with a foreseen movement time;
- altering the voltage (Vm) if the first movement time is different from the foreseen movement time, the foreseen movement time being such that the movement of the piston (5) will reach a maximum point (M), the point (M) being substantially close to the end of the piston (5) stroke.

2. A method according to claim 1, characterized in that the first movement time is a time (to) of remain of the piston (5) beyond a point (R) located at a point of the stroke of the piston (5), the point (R) being located at a point substantially close to the end of the stroke of the piston (5) and farther from the latter than the point (M), the method further comprising steps of:

- decreasing the voltage (Vm) if the time (to) is longer than the foreseen movement time, which is a time (tod), the time (tod) being a time shorter or equal to a time (tom), the time (tom) being a time of maximum stroke when the piston (5) reaches the point (M);
- increasing the voltage (Vm) if the time (to) is shorter than the time (tod).

3. A method according to claim 1 or 2, characterized in that the time (tom) is shorter than the time passed between a first and a second passage of the piston (5) by the point (R) when the piston (5) reaches the end of the stroke.

4. A method according to claim 3, characterized in that the first passage of the piston (5) by the point (R) occurs when the latter moves towards the end of the piston stroke, and the second passage of the piston (5) occurs when the latter displaces in the opposite direction and in a movement following that occurred at the time of the first passage.

5. A method according to claim 1, characterized in that the first movement time is a time (tc(n)) of duration of the movement of a complete piston cycle, this time (tc(n)) being compared with a foreseen movement time that is a time (tc(projected)), the time (tc(projected)) being an expected time of passage of the piston (5) by a point R and having a minimum value that prevents collision of the piston (5) at the end of the stroke, the point (R) being located at a point substantially close to the end of the piston (5) stroke and farther from the latter than the point (M), the voltage (Vm) being decreased if the time (tc(n)) is shorter than the time (tc(projected)).

6. A method according to claim 5, characterized in that the voltage (Vm) is decreased when the piston (5) is beyond the point (R).

7. A method according to claim 2, 5, or 6, characterized in that the voltage (Vm) is increased or decreased by means of a value (dV) applied to a voltage (V), the value (dV) being proportional to the difference between (tc(n)) and (tc(projected)).

8. A method according to claim 1, 2, 3, 4, 5, 6, or 7, characterized in that it comprises measuring the position of the piston (5) at the point R.

9. A system of monitoring the position of a piston (5), particularly a piston (5) of a linear compressor (1), the piston (5) moving along a stroke and being driven by a motor (2), the motor (2) being driven by a voltage (Vm), the system being characterized by comprising an electronic circuit (40), capable of monitoring the movement of the piston (5) from the passage at a point (R) close to a point (M) of the piston (5) stroke, the point (M) being substantially close to the end of the piston (5) stroke.

10. A system according to claim 9, characterized in that the electronic circuit (40) is capable of measuring a time (to) of remain of the piston (5) beyond the point (R) and comparing the time (to) with a time (tod), the time (tod) being shorter or equal to a time (tom), the time (tom) being a time of maximum stroke when the piston (5) reaches the point (M), the system further being capable of decreasing the voltage (Vm) if the time (to) is longer than a time (tod), and increasing the voltage (Vm) if the time (to) is shorter than the time (tod).

11. A system according to claim 10, characterized in that the electronic circuit (40) is capable of measuring a time (tc(n)) of duration of the movement of a complete cycle of the piston (5), and comparing the time (tc(n)) with a time (tc(projected)), the time (tc(projected)) being an expected time of passage of the piston (5) by a point (R), this point (R) being located at a point substantially close to

5. A method according to claim 1, characterized in that the first movement time is a time (tc(n)) of duration of the movement of a complete piston cycle, this time (tc(n)) being compared with a foreseen movement time that is a time (tc(projected)), the time (tc(projected)) being an expected time of passage of the piston (5) by a point R and having a minimum value that prevents collision of the piston (5) at the end of the stroke, the point (R) being located at a point substantially close to the end of the piston (5) stroke and farther from the latter than the point (M), the voltage (Vm) being decreased if the time (tc(n)) is shorter than the time (tc(projected)).

6. A method according to claim 5, characterized in that the voltage (Vm) is decreased when the piston (5) is beyond the point (R).

7. A method according to claim 2, 5, or 6, characterized in that the voltage (Vm) is increased or decreased by means of a value (dV) applied to a voltage (V), the value (dV) being proportional to the difference between (tc(n)) and (tc(projected)).

8. A method according to claim 1, 2, 3, 4, 5, 6, or 7, characterized in that it comprises measuring the position of the piston (5) at the point R.

9. A system of monitoring the position of a piston (5), particularly a piston (5) of a linear compressor (1), the piston (5) moving along a stroke and being driven by a motor (2), the motor (2) being driven by a voltage (Vm), the system being characterized by comprising an electronic circuit (40), capable of monitoring the movement of the piston (5) from the passage at a point (R) close to a point (M) of the piston (5) stroke, the point (M) being substantially close to the end of the piston (5) stroke.

10. A system according to claim 9, characterized in that the electronic circuit (40) is capable of measuring a time (to) of remain of the piston (5) beyond the point (R) and comparing the time (to) with a time (tod), the time (tod) being shorter or equal to a time (tom), the time (tom) being a time of maximum stroke when the piston (5) reaches the point (M), the system further being capable of decreasing the voltage (Vm) if the time (to) is longer than a time (tod), and increasing the voltage (Vm) if the time (to) is shorter than the time (tod).

11. A system according to claim 10, characterized in that the electronic circuit (40) is capable of measuring a time (tc(n)) of duration of the movement of a complete cycle of the piston (5), and comparing the time (tc(n)) with a time (tc(projected)), the time (tc(projected)) being an expected time of passage of the piston (5) by a point (R), this point (R) being located at a point substantially close to

the end of the piston (5) stroke and farther from the latter than the point (M), and decreasing the voltage (Vm) if the time (tc(n)) is shorter than the time (tc(projected)).

12. A system according to claim 10 or 11, characterized in that the electronic circuit (40) comprises a microcontroller (41) and an inverter (50), the microcontroller (41) accounting for the measurement of the times (to) and (tc(n)), and the inverter (50) accounting for the alteration of the voltage (Vm).

13. A compressor (1), particularly a linear compressor that comprises a piston (5), a valve plate (8,9) and a linear motor (2), the piston (5) moving along a stroke and being driven by the motor (2), the compressor (1) being characterized in that it comprises an electronic circuit (40), capable of monitoring the movement of the piston (5) from the passage at a point (R) close to a point (M) of the piston (5) stroke, the point (M) being defined in a region close to the valve plate (8, 9).

14. A compressor according to claim 13, characterized in that the electronic circuit (40) is capable of measuring a time (to) of remain of the piston (5) beyond the point (R) and comparing the time (to) with a time (tod), the time (tod) being a time shorter or equal to a time (tom), the time (tom) being a time of maximum stroke when the piston (5) reaches the point (M), the system further being capable of decreasing the voltage (Vm) if the time (to) is longer than a time (tod), and increasing the voltage (Vm) if the time (to) is shorter than the time (tod).

15. A compressor according to claim 14, characterized in that the electronic circuit (40) is capable of measuring a time (tc(n)) of duration of the movement of a complete cycle of the piston (5), and comparing the time (tc(n)) with a time (tc(projected)), the time (tc(projected)) being an expected time of passage of the piston (5) by a point (R), this point (R) being located at a point substantially close to the end of the piston (5) stroke and farther from the latter than the point (M), and decreasing the voltage (Vm) if the time (tc(n)) is shorter than the time (tc(projected)).

16. A compressor according to claim 14 or 15, characterized in that the electronic compressor (40) comprises a first controller (41) and an inverter (50), the microcontroller (41) accounting for the measurement of the times (to) and (tc(n)), and the inverter (50) accounting for the alteration of the voltage (Vm).

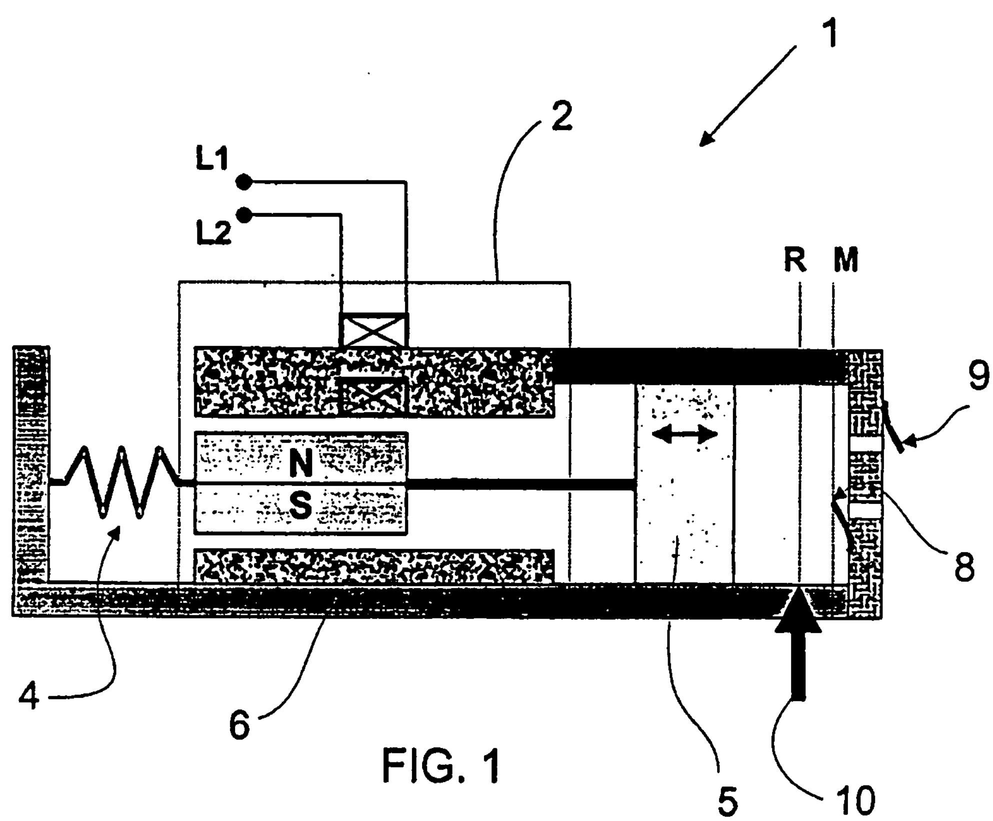

FIG. 1

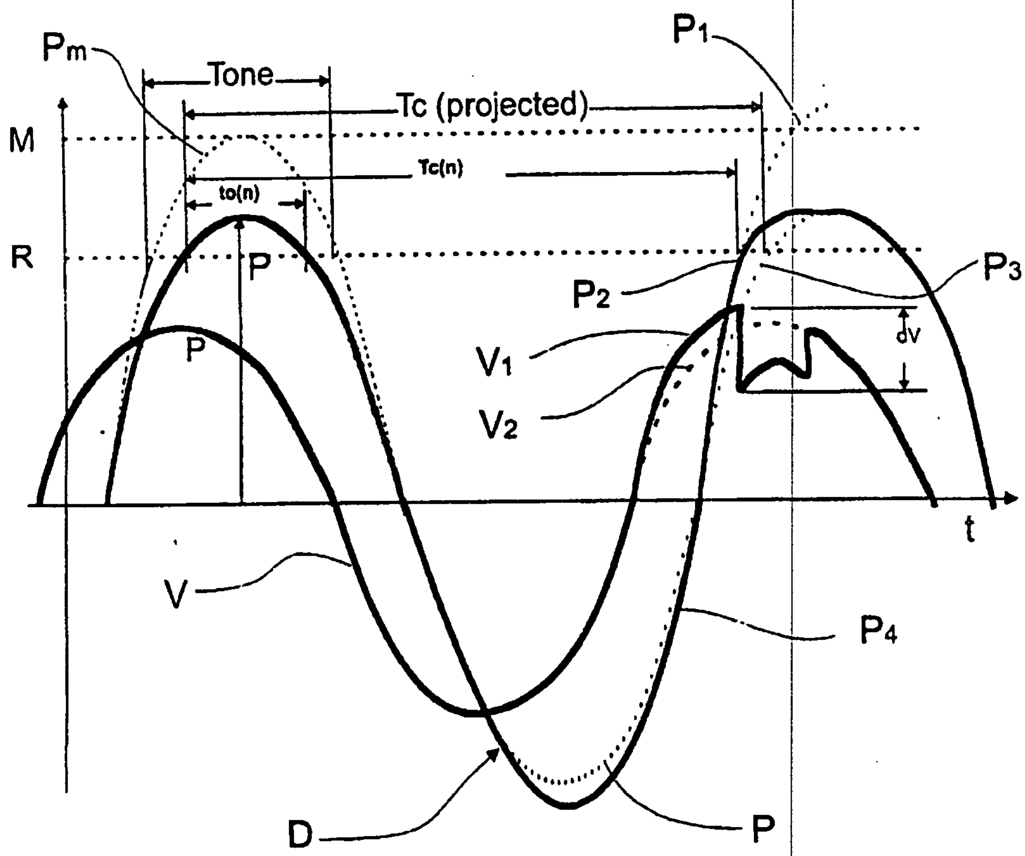

FIG. 2

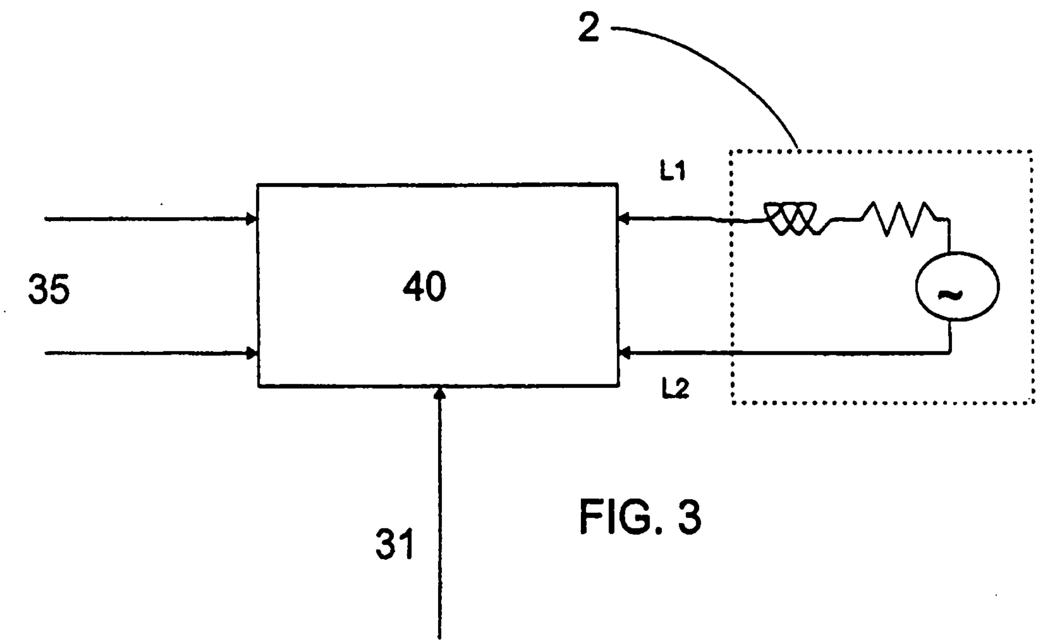

FIG. 3

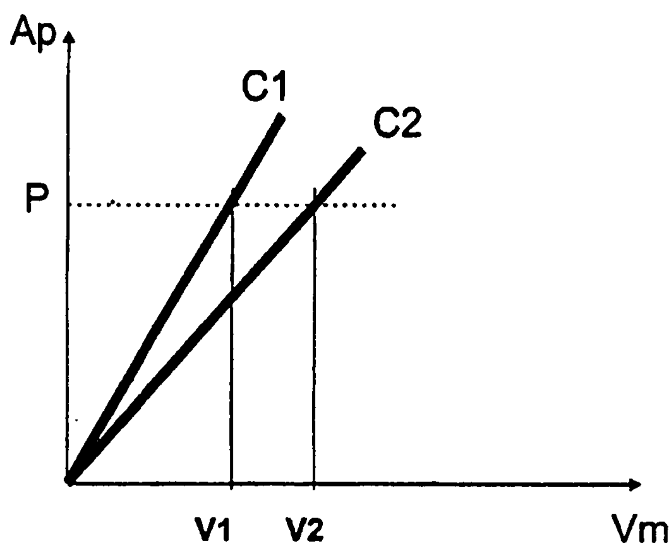

FIG. 4

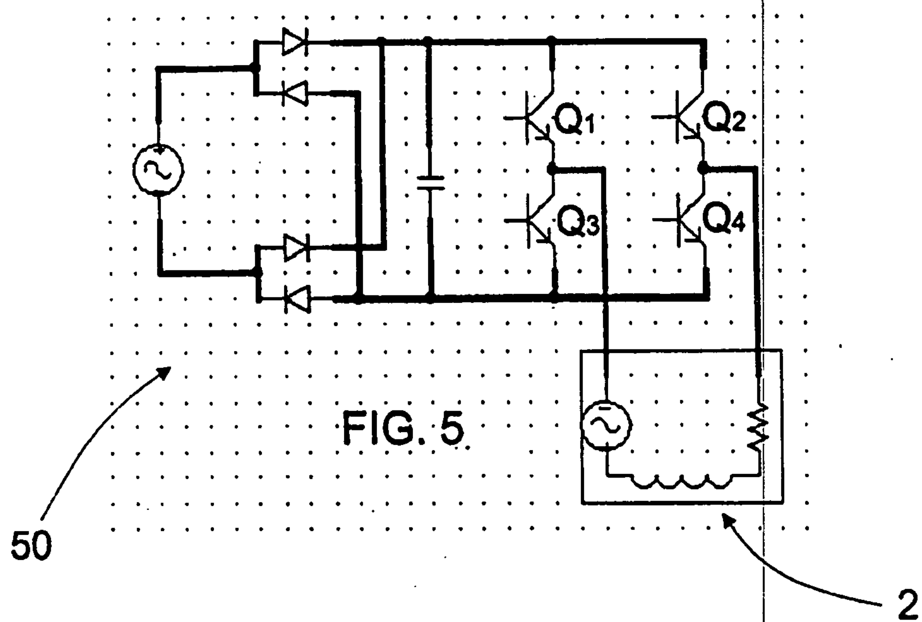
Q1
Q2
Q3
Q4
50
2

FIG. 5

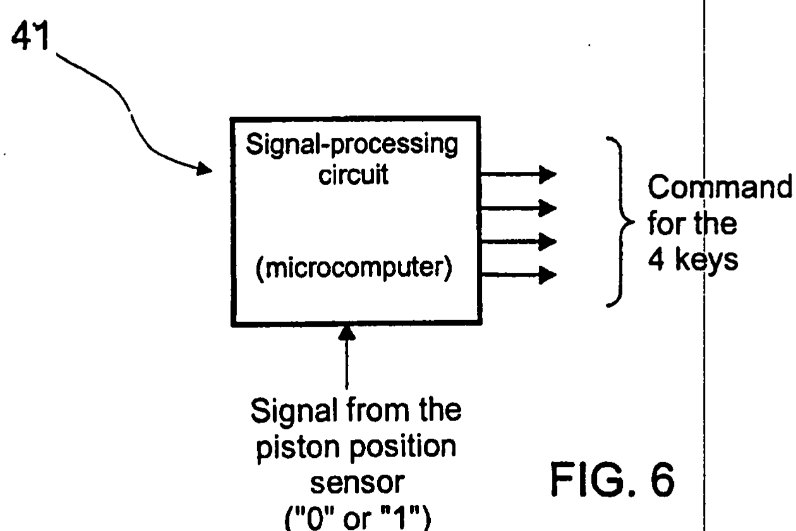
41
Signal-processing circuit
(microcomputer)
Command for the 4 keys
Signal from the piston position sensor ("0" or "1")

FIG. 6

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